Design and Development of 5MW Solar PV Grid Connected Power Plant Using PVsyst

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Abstract - *This study aimed at developing a standard procedure for the design of large-scale (5 MW) grid-connected solar PV systems using the PVSYST Software. The performance of the 5MW grid-connected solar PV system was also simulated over the guaranteed life of the system using PVsyst software. The project began with a broad database of meteorological data including global daily horizontal solar irradiance and also a database of various renewable energy systems components from different manufacturers. The standard procedure developed was validated in the design of a 5MW grid connected solar PV system established at shivanasamudram, mandya. In this paper, the grid connected solar photovoltaic power plant at the place called Belakavadi of Mandya district in the state of Karnataka established by Karnataka Power Corporation Limited in the year 2012. The photovoltaic power plant has a solar radiation of 6.10 kWh/sq.mt/day spread over 25 Acres of land. Operating module temperature varies from 15 to 40 degree centigrade, with a tilt angle of module 15 degree and guaranteed energy generated is 8.142 MU/Annum with 18.6% CUF. The various power losses (PV loss due to irradiation level, temperature, soiling, inverter, wiring, power electronics, grid availability and interconnection) and performance ratio are calculated. From simulation giving an annual PR of 84.4%.and also 25,615.6 Kg's of coal saving per day at the generating point by installing 5MW solar plant. This installation will be equivalent to planting 246,000 teak trees over the life time.*

Key Words: **Photovoltaic, Power, PVsyst, Meteorological Data.**

1. INTRODUCTION

Now day's conventional sources are rapidly depleting. Moreover the cost of energy is rising and therefore solar energy is the inexhaustible source that is abundant, pollution free, distributed throughout the earth and recyclable. India has very good conditions for the development of photovoltaic solar power systems due mainly to the high mean daily. The hindrance factor is its high installation cost and low conversion efficiency. Before going to this entire plant operation has to be done in practically, so taken the existing 5MW Shivanasamudra solar PV plant as a reference. The plant was installed on July-2013 and this is situated at Shivanasamudra, Mandya district, Karnataka. PV arrays consist of parallel and series combination of PV cells that are used to generate electrical power depending upon the atmospheric conditions (e.g. solar irradiation and temperature).

1.1 System Design and Objectives

The general objective in designing a Solar Power Plant to adequately match the capabilities to the load requirements of the consumer, at a minimum cost of the system to the consumer. In order to accomplish this, the designer will need to know the following types of questions about the system.

(1) Power Requirements, (2)Solar Data Availability, (3)Type and Size of Solar Power Plant Required, (4) Cost of Energy Produced, (5) Solar Power Viability, (6) System Characteristics, (7) System Requirement, (8) Evaluation Criteria, (9) Design Optimization, (10) Economic Viability and (11) Prospects of Cost Reduction.

1.2 Components Used in Solar Power Plants

Major components

1. Solar PV Model
2. Power Conditioning Unit/grid tie inverter
3. Utility Grid/Grid System

Minor components

1. DC array junction box
2. AC bus bar(LT and HT Switch gear)
3. Control room
4. Cables
5. Mounting structures
6. Earthing and lightening
7. SCADA (Supervisory control and data accusation system)
8. Water facilities/compound and fencing system and also roads inside the solar forms.

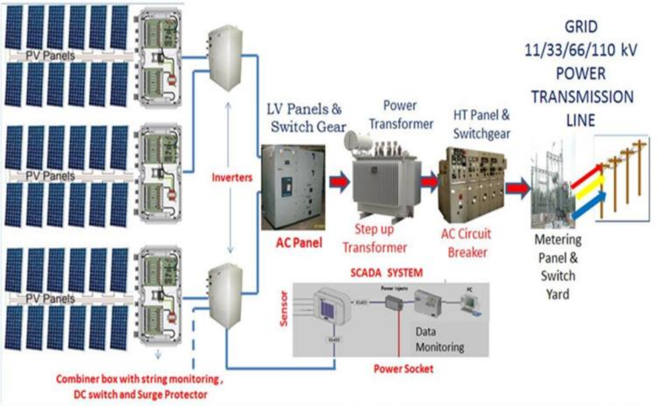


Fig-1: Schematic diagram of solar PV grid Connected plant

1.2 Factors should be Consider While Designing the System

1. The efficient sunshine hours in the location.
2. The proportion of the rainy/cloudy days in the location.
3. How many rainy-cloudy days for the system to work normally.
4. The database of the local weather report, such as sunshine hours, wind power, cloudy-rainy days, and natural disaster and so on.
5. The installation location should be wide, and make sure that there is no high building or other things to cover the solar panels & the sunshine.
6. Should take full investigation while designing the system,

a. Survey the local climatic conditions,

b. The current needs and future potential demands clearly,

c. Focus on performance and consider energy composition,

d. Structure, cost, transportation, construction conditions,

e. System protection should be complete and easy to operate and the Maintenance, other conditions and the maintenance should be a little as possible.

1.3 DC Side PV Plant Design

a. Modules in Series
1. Total MPP voltage at Max Module temperature > Inverter Min MPP Voltage
2. Total Open circuit voltage at Min Module temp < Inverter Max Voltage

b. Modules in Parallel
1. Max current shall not be more than Inverter Max Input current
2. No of Array combiner boxes – with or without string monitoring based on number of inputs selected for each box

c. No. of Main Junction Boxes – based on the Number of Inverter inputs

1.4 AC Side PV Plant Design

1. AC side cable
2. LT Switchgear and MV switchgear
3. Power Transformer (LV to MV)
4. HT Switchyard, Protection and Metering
5. Transmission lines

2. SITE AND TECHNICAL DETAILS

2.1 Site Location

The proposed site is located at Belakavadi village in Shivansamudram project in Malavalli taluk of Mandya district (Survey No's 369,370 and 371).

Latitude 12.3^0 and Longitude 77.16^0

Fig-2: 5MW Solar Plant Location

25 acres of land is identified and is taken to possession of KPCL in survey nos. 369,370 and 371 at a distance of at a distance of 20 Kms from Malavalli taluk. No wild life and no archaeological monument exist at the proposed site.

The site is well connected by rail and road. Mandya is located on Bangalore Mysore highway and nearest airport is located near Bangalore.

Other environmental aspects:
1. Wild animals: No wildlife is reported to be present in this area.
2. Health risk: No health hazards are caused by solar plant. In fact, the solar plant is environment friendly.
3. Archaeological and Historical places: There are no archaeological monuments or historical places in this area.

The detailed estimate and the power evacuation scheme along with proposed solar power plant building are enclosed hereby.

2.1 Solar PV Technology

Solar PV Technology converts sun's natural energy to useful electrical energy. Photo Voltaic modules are made of mono crystalline / polycrystalline solar cells connected in series and parallel modes. Type of solar panel used in this project is mono crystalline.

Mono crystalline solar panels are the most efficient type of solar panels but are also the most expensive. Their performance, somewhat is better in low light conditions. Overall efficiency on average is about 12-15%.warranted of this type of panels about 20-25 years.

Fig-3: Mono Crystalline PV Panels

Table -1: Solar Panel Specification

Watt	220 Watt
Voltage	360 Volts
Current	7.6 A
Type	Monocrystalline
No's of module	22560 no's
No's of modules per MW	4512 no's
Detail of series/parallel combination	24 no's in series, 940 no's in parallel string
Efficiency	14.3%
Temperature	Min 15 o and Max 40 deg c
Dimensions of single module(mm)	1655(L) × 995(w) × 50(T) mm Area of single panel = 1646725 (mm) Area of single panel = 1.64 meter^2
Tilt angle(slope) of PV Module	15 degree
Wind speed rating	150 Km/h
Mounting	Fixed Type
Output of the PV array to be connected to the PCU	Nominal 250 KW
Protective device	400 Volts under voltage relay

2.2 Inverter

GEC [Grid Export Condition] inverters are used here for suppressing the harmonics produced after DC to AC conversion.

20 numbers of 250KVA inverters are used in the plant.

Fig-4: GEC [Grid Export Condition] inverter

Table-2: Inverter Specifications

KVA rating	250 KVA
Input DC voltage	864 Volts DC
Input DC current	500 A
Output AC voltage	240 V ac (phase voltage) 240 V ac (line voltage)
No. of Phases	3-φ
Type	GEC [grid export condition]
Efficiency	Almost 90-93%
No of inverters	20

2.3 Grid Connecting Equipments

1) 1250 KVA, 0.415/11KV, 3 phase, 50Hz Transformer
2) Lightning arrestor, of suitable rating.
3) 66 KV switch yard consisting of Current Transformer, Potential Transformer, SF6/ Vacuum circuit Breaker, Bus bar, isolators , protection system etc. with incoming and outgoing feeders.
4) 66KV isolators.
5) Aluminum conductor ,of suitable diameter, aluminum armored cable confirming to IS 7098 suitable for carrying current from the switch yard up to D.P towers of required length for power evacuation (about 500m.) length.

2.4 Transformer

The transformer, transfers the electrical energy between two or more circuits through electromagnetic induction. Electromagnetic induction produces an electromotive force within a conductor which is exposed to time varying magnetic fields. these are used to increase or decrease the alternating voltages in electric power plant.
5 nos. 1250 KVA, 415/11000V, 3 phase, 50 Hz Dyn11, connected 5% impedance voltage, outdoor type transformers and accessories.

Fig-5: Transformer

Table-3: Transformer Specifications

KVA rating	1250 KVA
No of phases	3-φ
Frequency rating	50 Hz
Primary voltage rating	11 kVA
Secondary voltage rating	440 V
Primary current rating	64.18 A + (10-15% extra)
Secondary current rating	27.27 A + (10-15% extra)
Connections	Primary - delta (for suppressing Secondary - star 3rd harmonics) 10 to 25 taps in secondary
Efficiency	Almost 95 %
Extra features	Air cooled
No of transformers	5

2.5 Switch Yard

The 66KV switch yard is to be set up for power transmission/protection of the various systems as per the detailed specification.66KV switch yard shall consist of current transformers, potential transformers, sf6/ vacuum circuit breaker, bus bar , isolators ,protective devises etc.

Features of 66 KV switch yard:

a) Alternating current Circuit breakers
b) Voltage transformers
c) Current transformers:
d) AC disconnections (isolators) and earthing switches.
e) AC metal enclosed Switchgear & Control gear for rated voltages
f) Direct acting Indicating digital electrical measuring Instruments & accessories.
g) AC Energy meters
h) AC Watt hour meters
i) Electrical Relays for power system protection
j) Static protective relays
k) Push button/ switches
l) Bushings.
m) Common spec. for high voltage Switchgear & Control Gear standards
n) High voltage alternating current circuit breakers
o) Current transformers & Voltage transformers
p) Degree of protection provided by enclosure (IP code)

Fig-6: 66KV switch yard

2.6 Combiner Box/ Junction Box

Wires from the individual PV modules or strings are run to the combiner box, typically located on the roof. These wires may be single conductor pigtails with connecters that are pre-wired onto the PV modules. The output of the combiner box is one larger two wire conductor in conduit. A combiner box typically includes a safety fuse or breaker for each string and may include a surge protector.

Fig-7: Junction Box

3. DESIGN BASED ON SOFTWATE

Design and Estimate the results of 5MW solar power plant by using PVsyst software version 6.49.It is possible to have preliminary and as well as post evaluation test data for the feasible power generation.

The total system performance and efficiency of each systems of plant are evaluated by entering the specifications of a particular design. Design the system According to the above specifications of all components.

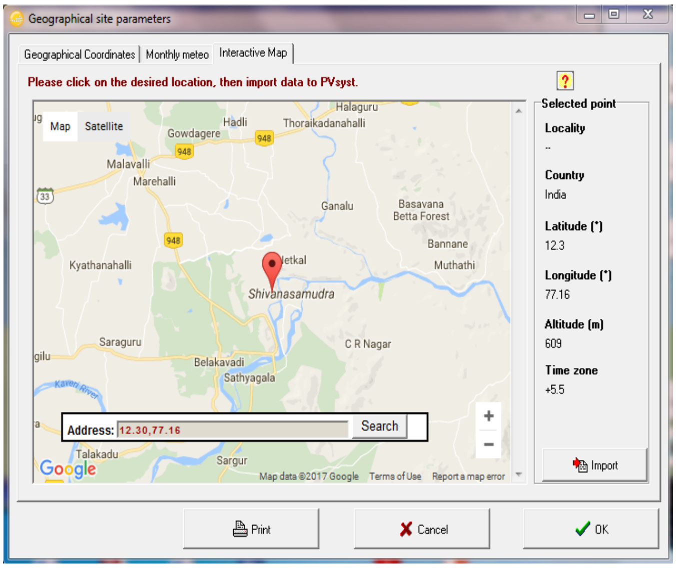


Fig-8: Geographical conditions

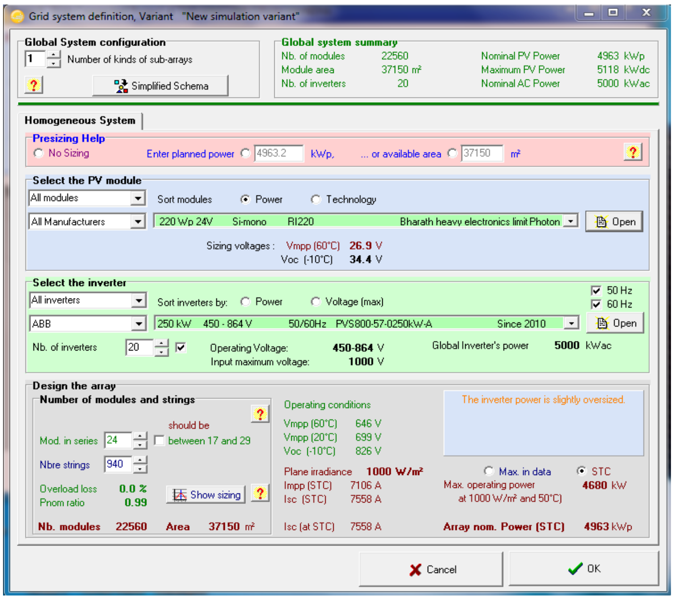


Fig-9: System Design (Solar module, inverter, array design)

4. RESULTS AND DESCUSSION

Table-4: Monthly Meteo values

Monthly Meteo Values Source MeteoNorm 6.1 station

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	
Hor. global	147.3	156.6	203.1	213.8	225.4	183.6	139.1	136.9	162.7	171.1	144.0	136.9	2020.6	kWh/m².mth
Hor. diffuse	33.1	36.9	51.8	64.4	78.3	89.5	87.8	77.0	74.6	50.7	37.7	32.4	714.0	kWh/m².mth
Extraterrestrial	266.8	263.9	314.6	316.7	327.5	313.7	324.3	325.4	308.0	299.0	264.3	258.0	3582.3	kWh/m².mth
Clearness Index	0.552	0.593	0.646	0.675	0.688	0.585	0.429	0.421	0.528	0.572	0.545	0.531	0.564	
Amb. temper.	19.6	22.4	27.9	31.6	33.0	31.7	29.1	28.1	28.9	27.9	24.1	20.3	27.1	°C
Wind velocity	1.8	1.8	1.9	2.3	3.2	3.3	2.9	2.5	2.0	1.1	1.1	1.5	2.1	m/s

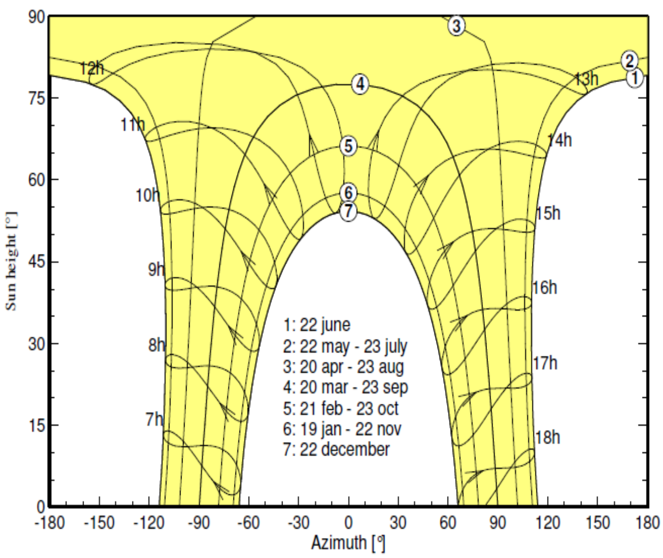


Chart-1: Solar Paths at Shivanasamudram (Lat. 12.3^{0}N, Long. 77.2^{0}E, alt. 609m

All the parameters underlying this simulation: Geographic situation and Mateo data used, plane orientation, general information about shadings (horizon and near shadings), components used and array configuration, loss parameters, etc.

4.1 Main Results

Produced energy: 8624 MWh/year
Specific production: The produced energy divided by the Nominal power of the array (Pnom at STC).
This is an indicator of the potential of the system, taking into account irradiance conditions (orientation, site location, meteorological conditions).
Specific Production= (Produced energy/Nominal Power of the array)
Specific Production=1738 kWh/kWp/year
Performance ratio: 84.4%

The yearly value can be an average like the temperature, or a sum, like the irradiation or energies. The meaning of the different variables is the following:

Table-5: Yearly values

	Glob Hor kWh/m²	T Amb ºC	GlobInc kWh/m²	Glob Eff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
January	147.2	19.6	167.0	162.0	744213	714433	11.99	11.51
February	156.5	22.4	171.6	166.7	756213	727665	11.86	11.41
March	203.0	27.9	210.7	204.9	913656	880387	11.67	11.24
April	213.8	31.6	208.7	202.4	897287	864042	11.57	11.14
May	225.4	33.0	208.0	201.1	891580	856793	11.54	11.09
June	183.6	31.7	167.4	161.3	725537	894091	11.67	11.16
July	139.1	29.1	130.2	125.2	571866	542237	11.82	11.21
August	136.8	28.1	131.5	126.7	574726	545501	11.77	11.17
September	162.4	28.9	163.4	158.1	712617	682351	11.74	11.24
October	171.0	27.9	182.2	176.7	795971	763512	11.76	11.28
November	143.9	24.1	161.2	156.5	711121	683190	11.87	11.38
December	136.9	20.3	157.3	152.5	700588	671360	11.99	11.49
Year	2019.6	27.0	2059	1994.	895375	8623762	11.76	11.27

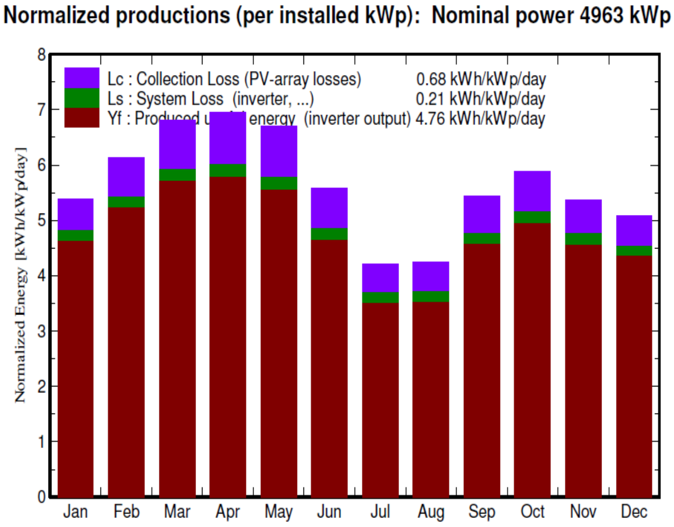


Chart-2: Normalized Productions (per installed kWp): Nominal power 4963 kWp

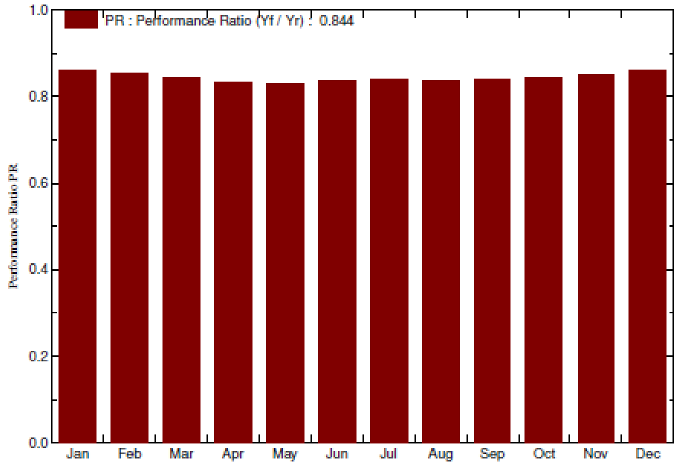


Chart-3 Performance Ratio

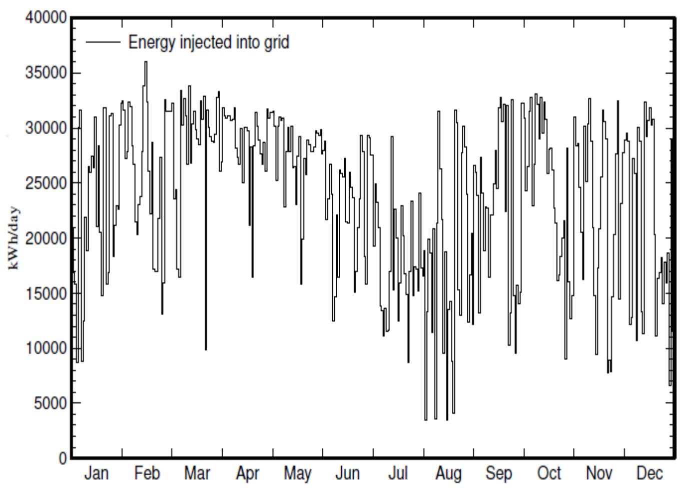


Chart-4: Daily System Output Energy

The highest power generation achieved was 35000kWh/day in the month of February. With the recorded insulation, average module temperature, plant efficiency of 6.10 kWh/m²/day, 27.07⁰C, and 84.4 % respectively.

The decline in the energy generation during the July and August period in chart 4 was mainly due to the higher plant downtime and more number of cloudy days during that period. The declination is clearly visible in chart 2 and table 5.

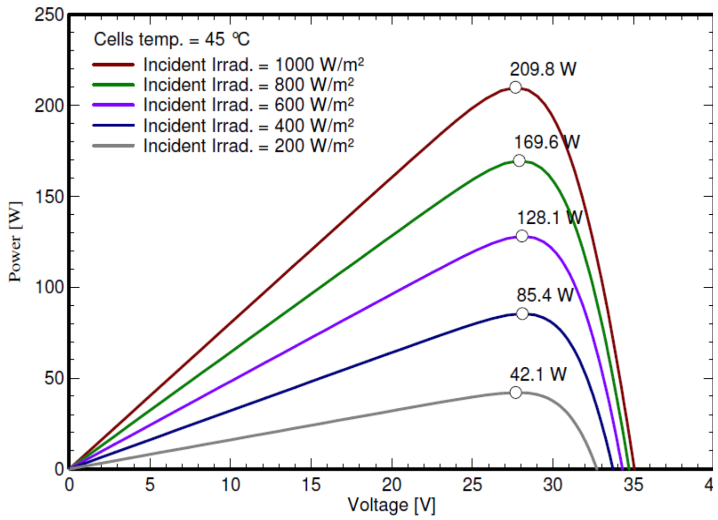


Chart-5: Power vs. voltage

From the chart 5, the maximum power reached at the incident radiation is about 1000W/m², a voltage 29 V, and at cell temperature 25-45⁰C with module efficiency is 13.4%.

Chart-6: Efficiency Profile of Inverter

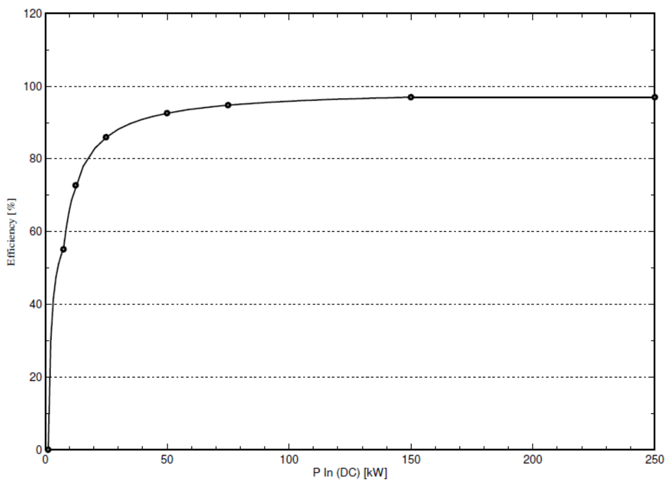
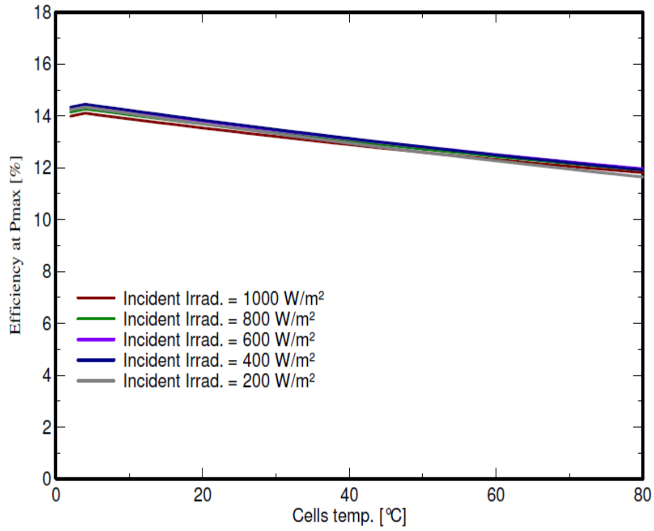


Chart-7: Efficiency vs. Cell Temperature



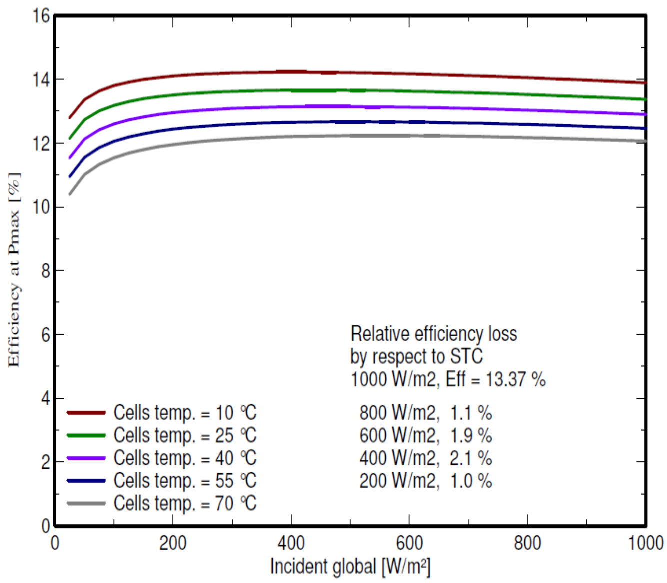


Chart-8: Efficiency vs. Incident radiation

Chart-7 shows the variation in energy generation of solar modules with insolation and the effect of effect of module temperature on their efficiency.

Energy generation shows direct dependent on the incident solar irradiation and reaches the maximum during peak insolation hours, the efficiency of the modules decreases and reaches the minimum during peak hours, the main reason is to increase in the module temperature. This negatively impacts the efficiency more during that hours. Efficiency of the module decreases from 13.3% at 30⁰C to 11.5% at 55°C.

It also clear that the temperature of modules increases with the increase in the solar irradiation and reaches the maximum during peak irradiation hours. in other side reduced conversion efficiency.

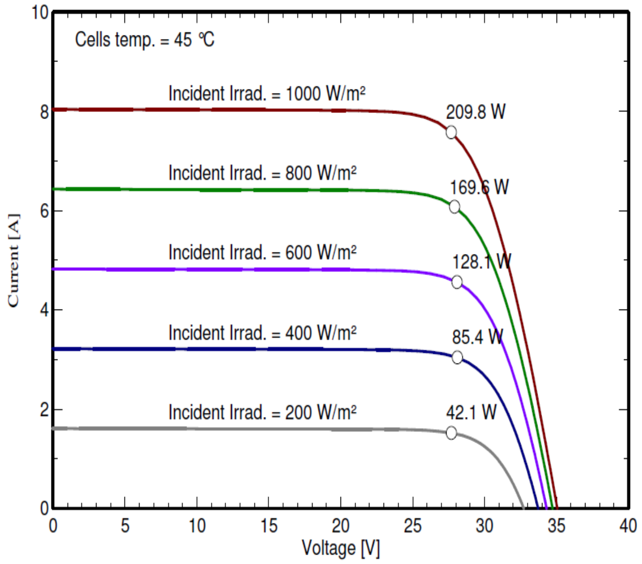


Chart-9: Characteristics of PV Module

It is clear from the Chart-9, that as the incident solar radiation (INSOLATION) level increases, the maximum current for a PV array also increases and has no significant effect on voltage when the temperature remains constant. The graph of efficiency versus the incident solar radiation under varying temperature condition is shown in Chart-8, which clearly demonstrates that as the temperature increases of PV module, the efficiency decreases at specific radiation level.

3. CONCLUSIONS

Using PV SYST V6.10 simulation software, the energy yield analysis for 5MW PV Solar power generation was performed for geographical site Shivanasamudram, Mandya.Which is located at latitude of 12.3^0 N and longitude 77.20E.And it was found that, for a horizontal global irradiation of 2019.6 kWh/m^2, performance ratio about 84.4%.The available energy at the inverter output which can be fed to the nearby grid is 8624.8MWh with a specific power production about 1738 kWh/kWp/year. This much amount of energy, which can be generated by establishing 5MW SPV plant at Shivanasamudram.

The impact of temperature variation on the performance of photovoltaic mono crystalline silicon was studied both on daily and yearly basis. It is observed that the efficiency of modules is more sensitive to temperature than the solar irradiation. The normal daily wise is that the efficiency of the plant is high during morning time but low during middle of the day and starts increasing from late afternoon. The efficiency of modules varies from 14.5% to 11.5% with variation in the averaged module temperature from 25^0C to 50^0C.Hence cooling of solar modules may be desirable to increase the efficiency.

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